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14. ABSTRACT

We perform theoretical and experimental investigations of microcantilever-based systems. Specifically, we study repeated impact oscillators for the determination of nano-scale surface mechanical properties, investigate the presence of stochastic resonance in the Atomic Force Microscope, and investigate enhancing throughput in microcantilever-based systems using arrays of microcantilevers.

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Dynamics and Control of Microcantilever-based Systems

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Summary

Microcantilever-based systems, which include Atomic Force Microscopes (AFM), is a rapidly growing class of sensors and actuators. The central mechanism of all these systems is a micro-fabricated cantilever with a sharp tip that interacts nonlinearly with a surface. This interaction is a source of rich signals that can be processed to determine many important physical parameters of the surface under examination. In addition, a microcantilever-based system can be used as a manufacturing tool that is capable of producing selective nanoscale surface adjustments. Critical to the operation of these systems is a complete analysis of the dynamical interaction of microcantilevers, tips and samples along with accurate identification and feedback control algorithms.

In this research program we pursuing theoretical and experimental investigations of microcantilever-based systems. Specifically, we are pursuing a study of repeated impact oscillators for the determination of nanoscale surface mechanical properties, investigating the presence of stochastic resonance in the AFM, and enhancing throughput in microcantilever-based systems using arrays of microcantilevers.

Throughput in atomic force microscopes is limited by the mechanical properties of the microcantilevers and by the detection and control design. A very important objective is to increase the throughput by improving both the design of the microcantilevers and the control system. Recently a new approach for increasing the throughput was developed where an array of microcantilevers are used to simultaneously image a surface. Control of the individual microcantilevers is achieved by a piezoelectric actuator and a piezoresistive sensor integrated on the microcantilever.

In this work we derived a model for an array of microcantilevers that are connected to each other through a common base, and are individually actuated. The sensors are also integrated on each microcantilever. This system is an example of a spatially-invariant system with a *distributed array of sensors and actuators.* We exploited the spatial invariance of the problem to design optimal $\mathcal{H}_2$ controllers for this array. We derived an analytic expression for the optimal controller in the transformed domain, and estimates of the communication range of each controller with neighboring microcantilevers. We are currently extending this work to capacitively actuated and sensed microcantilever arrays. Such an array is in the process of being manufactured and we will conduct experimental tests of our control schemes on these arrays.

Personnel Supported

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Publications

1. M. Basso, L. Giarre', M. Dahleh, "Complex Dynamics in a Harmonically Excited Lennard-Jones Oscillator: Microcantilever-Sample Interaction in Scanning Probe Microscopes, " *accepted in ASME Journal of Dynamic Systems Measurement and Control.*

2. B. Bamieh and M. Dahleh, "Energy Amplification in Channel Flows with Stochastic Excitation," *accepted in Physics of Fluids.*

3. D. D'Alessandro, I. Mezic, and M. Dahleh, "Some Ergodic Theorems for Sequences of Measure Preserving Transformations ," *to appear in the Journal of Statistical Physics.*

   Submitted

4. M. V. Salapaka, M. Dahleh, A. Tesi, and A. Vicino, "Nominal $\mathcal{H}_2$ Performance and ℓ_1 Robust Performance," *submitted to IEEE Trans. Automat. Contr.*

5. M. V. Salapaka, D. J. Chen, and J. P. Cleveland, "Stability and Sensitivity Analysis of Periodic Orbits in Tapping Mode Atomic Force Microscopy," *submitted to Physical Review B.*

Theses

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